PROGRESS IN HEALTH AND SAFETY
Contributions of Agricultural Research at the Southern Regional Research Center

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INTRODUCTION

Contributions of agricultural research to health and safety? The obvious contribution is, of course, better nutrition; beyond that, the relationship between agricultural research and better health and safety may appear to be indirect.

Instead, the relationship is often direct and the contributions major. In a recent address (*65*),[2] Frederic R. Senti, Assistant Administrator on the National Program Staff of Agricultural Research Service, cited some examples: Development of processes for the mass production of penicillin . . . eradication of trichinosis . . . control of tuberculous meningitis and miliary tuberculosis . . . discovery of a new source of an enzyme that inhibits leukemia. "And," he said, "the implications [of agricultural research] for bettering the health and safety of future generations are incalculable."

In this context, the Southern Regional Research Center (SRRC),[3] as part of Agricultural Research Service, has participated in notable achievements in the health field. Often conducted in cooperation with medical institutions and other organizations, this research has already had a major impact on the physical well-being of Americans and may affect others throughout the world. Much of it is particularly noteworthy because the health benefits were achieved *in addition to* other practical benefits—such as an improved product or more efficient processing—for the farmer, the consumer, or industry.

RESTORATION OF HEALTH

Control of Disease

Hemophilia

The Center's contribution to hemophilia therapy is a prime example of the diverse and multiple benefits of research. With the objective of improving food products, scientists there were conducting research on the isolation and characterization of various peanut constituents when a seemingly unrelated incident occurred. In 1957, a university professor, alert to possible effects of ingested food upon his own hemophilia, observed that shortly after he ate a handful of roasted peanuts, the tenderness in an affected knee rapidly decreased, an indication that bleeding in the active hematoma had stopped (*13*). On a regimen of large amounts of peanuts, he continued to improve, as did several other hemophiliac volunteers.

As a result, the peanut research at SRRC was extended, in cooperation with the Department of Zoology at Louisiana State University, to include isolation of the factor that relieved hemophilia. After the oil was extracted from lightly roasted peanuts with petroleum ether, the defatted meal was further extracted with 95 percent ethyl alcohol (*28*). This process successfully removed the active factor, which had both myotonic and local

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[2] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

[3] Until July 1, 1972, the Southern Regional Research Laboratory in New Orleans (now called the Southern Regional Research Center) was headquarters for the Southern Marketing and Nutrition Research Division of Agricultural Research Service. Until then, the Division had field stations at Olustee, Fla.; Weslaco, Tex.; and Knoxville, Tenn.; and, until July 1, 1971, also at Winter Haven, Fla., and Raleigh, N.C. Much of the research reported here was conducted by these and predecessor organizations. For simplicity, the field stations will be identified, but all predecessor parent organizations will be referred to by the present name.

vasoconstrictor properties. Its effectiveness was later increased by preparation of a 50,000-fold concentrate.

For the approximately 100,000 hemophiliacs in this country at that time, the standard treatment to relieve internal or external bleeding was massive transfusions of plasma. Even partial recovery was slow and painful, frequently requiring hospitalization. In contrast, treatment with the peanut extract or concentrate usually induced hemostasis in a fraction of the time required with the conventional procedure, sometimes among hemophiliacs who were refractory to plasma and whole blood. Clinical studies conducted by medical researchers in Holland, Denmark, France, Hungary, and Germany independently confirmed the hemostatic properties of the peanut constituent. Although preparations containing an antihemophilic factor from blood can now be administered to control bleeding (*18*), use of the peanut factor once offered an important option in the treatment of hemophilia.

Necrosis of Subcutaneous Fat

Certain types of surgery, such as cardiovascular repair, require artificial cooling of the patient's body to decrease the rate of metabolic processes. However, when young children were subjected to general hypothermia, there was often a postoperative complication, necrosis of subcutaneous fat. Surgeons at Vanderbilt School of Medicine referred this problem to SRRC chemists, who were then developing analytical methodology for determining the chemical composition of fats.

In cooperative research, composition of body fats in weanling pigs was determined to establish its effect on subcutaneous fat necrosis after general hypothermia.[4] Besides confirming the cause-and-effect relationship between hypothermia and necrosis, the results showed that the complication was prevented when the test animals ingested rations that contained large amounts of unsaturated fats. It was postulated that necrosis had occurred in children because their fat, unlike that of adults, contains a relatively low percentage of unsaturated fatty acids and, as a consequence, has a relatively high freezing point.

Byssinosis

For many years, a respiratory ailment called byssinosis, or brown lung, has been observed among workers in cotton textile mills. However, the problem is not confined to cotton, but also extends to flax and probably to hemp.

The first steps in controlling or eradicating the disease are to identify, isolate, and establish the causative agent and then to develop a simple, inexpensive, and rapid method of determining its presence in samples of textile fibers and dust. This type of research is just getting underway at SRRC. In addition to important health benefits for workers, this research may lead to an economical deactivation procedure, since only materials that actually contain the causative factor would have to be treated.

Products for Medical Use

Sutures and Bandages

Much of the research at SRRC concerns cotton; a natural objective, therefore, was to develop improved sutures and bandages from this fiber.

The possibility of sterilizing sutures by use of radiation was investigated. Application of a sterilizing dose of electron or gamma radiation to unmodified cotton surgical sutures caused only about a 15- to 20-percent reduction in breaking and knot strengths (*12*). As a result, a large medical supplier has been using gamma radiation for sterilization of sutures for some time, and a number of companies may soon extend commercial application to other medical and personal products.

A cotton bandage (*33*) developed at SRRC during World War II proved so superior that over 200 million have been sold. Particularly suitable for bandaging joints, contoured areas of the body, and burns, the bandage clings to itself, conforms readily to shape, and has sufficient elasticity to permit circulation of blood and freedom of movement (fig. 1).

This clinging, two-way stretch bandage is made by a process called slack mercerization. An open-weave cotton fabric or gauze held without tension is treated with a 20- to 25-percent solu-

[4] Adams, J. E., Foster, J. H., Faulk, W. H., Stansbury, M. F., and Scott, H. W., Jr. Experimental production of subcutaneous fat necrosis by general hypothermia: Relation to the chemical composition of fat. Vanderbilt University School of Medicine, Nashville, Tenn., and Southern Regional Research Laboratory, New Orleans, La., 1954, 11 pp.

FIGURE 1.—Two-way stretch cotton bandage conforming to contours of head.

tion of sodium hydroxide. As the fabric shrinks in all directions, individual yarns develop spring-like crimps, which impart the clinging and elastic properties.

Although quality rather than price is the determining factor in the extensive use of the bandage, it costs far less than the elastic rubber-rayon bandage previously used. In fact, by replacing this conventional type, it saved the Armed Forces $13.5 million during the Korean conflict alone. Now offered to retail, hospital, and other institutional markets by at least four surgical supply houses, this bandage has been described (*40*) as "so talented . . . that even an amateur can do a neat, comfortable job on joints and other hard-to-fit parts of the human anatomy."

Infusions and Injections

For many years, a fat emulsion suitable for intravenous nutrition has been sought to prevent persistent weight loss in patients fed intravenously for long periods. One approach toward solving this problem was a high-calorie emulsion developed by SRRC scientists in research supported by the Office of the Surgeon General and conducted in cooperation with the U.S. Army Medical Research and Nutrition Laboratory and several medical schools. This physically stable emulsion from cottonseed oil was made possible by development of a more efficient chromatographic method for isolation of pure egg lecithin, which was used as the sole emulsifier (*77*). Although the emulsion was not developed sufficiently to administer to humans, medical researchers and industry have recently expressed interest in it. Results from the research may prove useful in the future, particularly as more information becomes available on the mechanisms of transport, deposition, and retrieval of fat in the bloodstream.

Research at the Center also contributed to the first successful penicillin formulation that was both long-acting and injectable. A highly refined, bleached, and deodorized peanut oil was supplied to U.S. Army medical personnel for evaluation in a formulation containing penicillin and beeswax. In this combination, known as the Romansky formula (*63*), the peanut oil and beeswax slowed the absorption of penicillin so that high levels could be maintained in the blood for a long time. Information that Center scientists furnished the pharmaceutical industry greatly facilitated preparation of the highly refined oil then needed for this type of injectable penicillin.

Another oil studied at SRRC—jojoba—also proved useful in penicillin preparations. In fact, at one time it was reported to be the best liquid wax for stabilizing injectable penicillin. In the late 1950's, publication of research results on the chemistry (*43*) and processing (*42*) of jojoba oil stimulated interest in its potential for use in a variety of products, such as lubricants and emulsifiers. This interest recently revived because jojoba holds promise for providing employment to Indians and other residents of the southwestern United States and northern Mexico. Its unique properties may permit it to replace sperm whale oil, an expensive imported product from an endangered species.

Ointments and Coatings

A new series of fats, the acetoglycerides, was developed by chemically modifying the glycerides that occur in ordinary fats and oils (*26*). The unique properties of the acetoglycerides

make them useful in such a variety of products, including ointments and coatings, that about 10 million pounds[5] have been produced commercially.

One type of acetoglyceride remains plastic even after it solidifies and has the additional advantage of not being greasy. Another type melts just above room temperature and is extremely resistant to oxidation. Blends of these two products have been approved by the Food and Drug Administration for use in certain ointments, creams, and cosmetics. Spread in a thin, almost invisible film, these acetoglycerides are not absorbed by the skin but retard the loss of moisture and the passage of oxygen and other atmospheric gases.

Acetoglycerides have also been used as coatings for pills and other edible products. Some of the food products tested by the astronauts in space have been glazed with a mixture of an acetoglyceride and other ingredients. This glaze performed well despite high vibration, high humidity, and low pressure, and resisted spoilage in an atmosphere of pure oxygen.

MAINTENANCE OF HEALTH

Better Nutrition

The development of new and better food products and processing has long been an important part of research at SRRC. This research has increased the utilization of farm commodities; provided more nutritious, safer, and more convenient foods to American families; offered more profitable applications to industry; and made contributions toward solving the worldwide problem of malnutrition.

Oilseeds

To provide sufficient protein in a form acceptable to a specific population is, of course, a major goal throughout the world. Utilizing a crop grown in many countries, the liquid cyclone process (LCP) now provides a method of preparing an edible, high-protein flour from glanded cottonseed (*29*). A company capable of producing about 3 tons of the flour a day was built in India; a plant to yield 25 tons a day has recently been constructed in Texas; and another firm is implementing a broad program to develop and market protein products from the flour, including the total production of the new LCP plant. Industrial companies and governments around the world have expressed interest in the process, and economc feasibility studies are being considered at various locations.

In fact, cottonseed processing recently entered a new era when the Food and Drug Administration approved LCP flour for use in foods (*4*). The use of cottonseed for food had previously been limited because it contains gossypol (fig. 2), a pigment that may cause physiological effects. But the new process obviates this difficulty —the liquid cyclone concentrates most of the protein in one fraction and simultaneously transfers most of the gossypol into the other fraction. The first product, a fine flour that is bland in flavor and light in color, contains 65 to 70 percent protein by weight; it can be used in bakery items, as a meat extender, and in cereals and

FIGURE 2.—Cross sections of glanded cottonseed (*left*) containing gossypol and related pigments and glandless cottonseed (*right*).

[5] Decossas, K. M., unpublished information, 1973.

snacks. The other product, a coarse meal, can be mixed with a feed product for ruminants.

The economics of the process is favorable. The high-protein fraction used for food will cost about 20 cents to produce and will sell for 30 to 35 cents, competitive with soybean protein concentrate. Other attractive features are that the process is continuous and much of the equipment required is the same type as that now used in hexane extraction plants.

Cottonseed products have potential in a wide variety of foods (fig. 3) because of their functional nutritive properties. Both LCP flour and flour from the recently developed glandless cottonseed (fig. 2) have been used to prepare isolates, which contain at least 90 percent protein. One isolate's unusual property of acid solubility makes it particularly valuable for the preparation of certain protein-fortified beverages, such as citrus drinks; this isolate has interesting whippability characteristics at acid pH. The other isolate has outstanding nutritional characteristics. The glandless flour has also been used to prepare concentrates, which contain about 70 percent protein (*51*). Major markets for the concentrates appear to be in bakery items, meat products, and textured meat analogs.

Paradoxically, another research product that can furnish palatable protein for residents of developing countries can also provide a crunchy snack to dieters in this country. This versatile food is called partially defatted peanuts.

Since the oil in roasted peanuts contains most of the calories, it is axiomatic that removal of the oil would remove most of the calories. But how to remove the oil and still retain the peanut's flavor, aroma, shape, and texture presented a problem.

The solution proved deceptively simple. About 60 percent of the oil is pressed out mechanically, the resulting misshapen peanuts are heated in boiling water to restore them to their original size and shape, and they are then dried and roasted (*73*). The resulting product has a higher proportion of protein but fewer calories than roasted peanuts.

In addition to their appeal as a flavorful snack, partially defatted peanuts can also be used in soups and other processed foods. The pressed but unswollen peanuts, low in bulk and rich in protein, should be attractive for export to developing countries. In fact, the method can be used to achieve a wide variety of products, since many ingredients can be added during reconstitution—not only flavorings, such as salt, cheese, onion, chocolate, or spices, but also ingredients for nutritional fortification, such as vitamins, minerals, and essential amino acids. In addition, the SRRC process has been successfully extended by

FIGURE 3.—Some types of foods in which high-protein cottonseed products can be used.

industrial researchers to produce simulated black walnuts (*1*) and pecans (*2*) from peanuts.

Besides developing edible proteins from oilseeds, scientists at the Center have created a number of interesting products from the fatty components of the seeds. Three examples are sucrose esters, glucoside esters, and cocoa butterlike fats.

Sucrose esters made by a new process (*27*) are evoking much interest from industry. Since this process eliminates the need for the conventional solvent, which leaves a toxic residue, it opens the huge food market to these sugar esters. They could be used as emulsifiers in a wide variety of products—frozen desserts, cakes, whipped toppings, coffee whiteners, salad dressings, and margarine. Cooperative research by the former Crops Research Division of Agricultural Research Service and the Kansas Agricultural Experiment Station showed that the addition of small amounts of sucrose esters improved volume, crumb grain, and softness of bread to which protein supplements had been added (*57*). Thus, sucrose esters made by the new method may not only displace established products that are physiologically less desirable but may indeed meet needs that are now unfilled.

In more recent research, a method was developed for preparing fatty acid esters of glycerol glucosides (*25*), another promising type of food ester. These agents are highly surface active and have excellent potential as food emulsifiers, for example, in improving the quality of cakes and high-protein bread.

Researchers at SRRC have also devised a simple, economical process for preparing specialty fats with the desirable characteristics of cocoa butter—hardness at room temperature and a very short melting range (*49*). They are made from the stearine obtained in large quantities as a byproduct from the commercial solvent winterization of cottonseed oil. The stearine is hydrogenated, and the product is then fractionated. This process is particularly attractive because it transforms a low-priced domestic byproduct into the equivalent of a much more expensive imported fat.

Fruits

Frozen orange concentrate (*50*) certainly needs no description—it is an almost ubiquitous food in America. Developed by scientists at Agricultural Research Service's Winter Haven laboratory in Florida in cooperation with the Florida Citrus Commission, it had an immediate and profound effect upon the development and economy of the citrus industry. It has also provided an impressive statistic: The value of frozen orange concentrate is now $1 million a day at the consumer level. However, not content to rest on this statistic, researchers at Winter Haven have continued to develop versatile new citrus products.

Preparation of one type of product—citrus crystals, either orange or grapefruit—begins with commercial frozen concentrate and involves five basic steps: (1) Formation of foam, (2) dehydration, (3) densification, (4) classification by particle size, and (5) packaging (*8*, *10*, *11*). The crystals readily dissolve in water to yield a fresh-tasting juice. Since they are lightweight and do not need refrigeration, they are attractive for both domestic and export markets. In fact, in addition to appealing to earthbound consumers, orange crystals have been enjoyed by astronauts on all space missions since Apollo 13.

Orange crystals have been pressed into small, flavorful disks (*7*) that have all the nutritive advantages of orange juice, including caloric content, vitamin C, other vitamins, and minerals (fig. 4). Similar disks have also been prepared from grapefruit. These citrus tablets, which can

FIGURE 4.—An orange juice tablet that has the nutritive advantages of the juice.

be eaten like candy, also have potential in convenience foods, such as pie and cake mixes; in pharmaceuticals; and in specialty markets, such as foods for campers, dieters, or military field units.

Researchers at Weslaco, Tex., have developed a technique for freeze-drying an avocado mixture to yield a product that can be stored successfully without being frozen (*47*). Canned under nitrogen or vacuum, the formulation keeps for 16 weeks at 68° F and for 48 weeks at 40° F. In addition to its use in guacamole salad, the rehydrated avocado can be used alone as a dip or combined with other ingredients.

Vegetables

Research on sweetpotatoes not only has produced nutritious convenience foods for military and civilian consumers but also has provided profitable outlets for the odd-shaped, oversized sweetpotatoes that do not meet standards for the fresh market. During World War II, dehydrated sweetpotato cubes for the Armed Forces were developed in cooperative research between SRRC and the Quartermaster Food and Container Institute for the Armed Forces. Later, the same cooperators developed precooked, dehydrated sweetpotato flakes (*19*). They can be reconstituted in less than a minute and have the taste and color of freshly cooked, pureed sweetpotatoes. During the decade that the flakes have been commercially available, production has sometimes amounted to 1.5 to 2.0 million pounds annually.[6]

Pure-culture fermentation of cucumbers (*23*) is a process by which undesirable organisms in the brine are inactivated and the bacteria best suited for producing high-quality pickles are introduced. It was the first breakthrough in the basic process for fermenting cucumbers in more than 4,000 years of pickle history. Developed by scientists at Raleigh, N.C., in cooperation with the North Carolina and Michigan Agricultural Experiment Stations and the National Pickle Packers Association (now Pickle Packers International, Inc.), it enables processors to improve quality, offer new products, reduce costs, and decrease disposal problems. Flavor characteristics of the final product can be tailored by selecting the type of cucumber and bacteria. In contrast to the lengthy conventional method of pickling, pure-culture fermentation is complete within a week, although flavor continues to develop for a longer period. This process has also been applied to tomatoes, peppers, carrots, and other vegetables (*21*) and to Manzanillo olives (*22*).

Researchers at Winter Haven, Fla., have devised a process to make the unique flavor and texture of fresh celery readily available to consumers throughout the year. Although dehydrated celery has long been commercially available, conventional drying methods deprive it of its fresh flavor and aroma, toughen the fibers, and impair the texture. The product is also difficult to rehydrate fully. Now an easily reconstituted, dehydrated celery of good texture and color can be produced by a combination of freezing and explosion-puffing (*74*) or by explosion-puffing alone (*70*). The improved quality of these products is due primarily to the porous structure imparted during puffing, which permits more rapid final drying and more complete and rapid rehydration.

Rice

Research has greatly increased the diversity of products in which rice can be used. Two examples are high-protein foods and extruded products.

Observations by Spanish scientists (*58*) that the protein in conventionally milled rice is largely concentrated in the periphery of the kernel suggested a practical application to researchers at the Southern (*38*) and Western Regional Research Centers (*39*). Using commercial rice-whitening machines, such as the Satake,[7] they removed this fraction to yield two food products, high-protein flour and residual kernels. The flour is rich in vitamins and minerals and contains as much as 20 percent protein, compared with about 8.5 percent for the entire kernel before the outer layers are removed. In addition to its potential in high-protein foods, it could also be used as an easily digestible, nonallergenic in-

[6] Decossas, K. M., unpublished information, 1973.

[7] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

gredient in baby foods, geriatric diets, and other specialty and convenience products. When cooked, the residual kernels are whiter, less tacky, and more flavorful than the original kernels. When the process is applied to broken rice, the residual kernels are suitable for industrial uses, such as brewing.

In other research, the cooker-extrusion-expansion process was used on various forms of rice, such as brewers' rice, whole grain white and brown rice, and rice cracked to grit size (*56*). The viscosity characteristics of the extruded products make them well suited to use in porridge, gruel, and either hot or cold beverages. In addition to having nutritive value themselves, they can be used to hold oilseed flours in suspension and thus to yield a high-calorie food. A variety of flavorings can be added to the bland white rice products; the brown rice products already have a pleasant, malt-like flavor.

Sugar

Each year, every American consumes almost his weight in sugar—over 100 pounds! Therefore, research on sugar, though a small part of the total program at SRRC, is important to many consumers and to a large industry. For many years, research has been conducted on sugar from sugarcane; more recently, the feasibility of recovering sugar from sweet sorghum was also investigated.

Current research on cane sugar, conducted in cooperation with the Cane Sugar Refining Research Project, Inc., is directed toward solving one of the most serious problems in sugar refining, identification and control of colorants (*24*). Important in themselves, colorants may also contribute to difficulties with floc, taste, and odor. Information about these pigments is requisite to the development of cheaper, more efficient methods of refining.

In research on sweet sorghum, pilot-plant procedures were developed for clarifying the juices and removing their objectionable starch contents. Raw sugars of good quality were crystallized from the sirups and molasses. These successful preliminary results (*66*), obtained in cooperation with the Texas A&M University Research and Extension Center at Weslaco, Tex., suggest that sugar can be produced commercially from sweet sorghum juices to supplement the production of cane sugar.

Sanitation of Clothing and Textiles

Soil Resistance and Soil Release

With respect to soiling, the ideal fabric has two characteristics: (1) During use, it *resists* soiling, and (2) during laundering, it *releases* soil. Unfortunately, to complicate matters for homemakers and for scientists, the same treatment that makes a fabric resist soiling during use often makes it retain soil during laundering.

Several years ago, fluorine polymer finishes were introduced commercially to impart oil- and water-resistance to certain textiles, particularly upholstery fabrics. However, these early finishes presented difficulties. Once oily stains or soil were rubbed in, they became almost impossible to remove, partly because the fabric also resisted wetting by water. A similar problem occurred with the first wash-and-wear garments, which actually *attracted* dirt from the water during laundering, motivating one SRRC scientist to coin the phrase "wash-and-swear."

For many years, it had been known that adding carboxymethyl cellulose (CMC) to the last rinse water facilitated the removal of soil from cotton fabrics (*20*). The mechanism of cleaning was thought to be that CMC flaked off the surface of the fibers, carrying particles of soil with it. However, later research showed that CMC need not be removed; in fact, even when it was bonded to the surface of cross-linked cotton fabrics, it was still an efficient soil release agent (*6*). This characteristic was due in part to CMC's hydrophilic nature: it attracted water rather than repelled it.

Research on CMC and on soiling of fabrics having various surface properties led to the development of new and far better fluorocarbon finishes for textiles (*55*). Like the older fluorine polymers, they resist oily soils and stains, but, like CMC, they permit water to wet and remove soils during laundering. These new finishes—the solution to a difficult problem—provide a typical example of how the scientist helps the consumer through research.

Laundering Procedures to Control Micro-organisms

Since 1930, USDA has been concerned with the hygienic care of textiles. Early research in this area was concerned with factors influencing bacterial and viral contamination, survival, infectivity, and release. A bulletin issued in 1964, updated several times since then, explained how

to control bacteria during home laundering, providing detailed instructions on time and temperature, types of disinfectants, and sanitization of equipment (*71*).

Two contracts supervised by the Textiles and Clothing Laboratory in Knoxville, Tenn., have provided additional information on hygienic methods of cleaning fabrics (*45*). In one project, conducted by WARF Institute, Inc., home laundering variables were investigated for a number of chemically finished fabrics. Laundering in hot water (120° F) with a double level of chlorine and an anionic detergent gave the greatest control of bacteria. However, even the amounts normally used considerably reduced bacterial and viral count. In the other project, scientists at the Southern Research Institute, using contaminated fabrics, obtained quantitative data on the viricidal effectiveness of standard laboratory and commercial coin-operated drycleaning processes. The commercial process was superior in eliminating poliovirus but not vaccinia or herpes viruses. When commercial drycleaning solvent that contained these three viruses or rhinovirus was heated for an hour at 60° C, there was complete loss of infectivity. These projects have provided information that is directly applicable to the important public health problem of sanitizing textiles.

PROTECTION FROM HAZARDS

Flame-Retardant Products

Each year, burns cause about 13,000 deaths, 2 million injuries, and loss of nearly a billion dollars in hospital costs alone; however, experts agree that 75 percent of burn accidents are avoidable.[8] In recognition of this major problem and of the potential for solving it, scientists at SRRC have developed processes for imparting flame retardancy to a variety of products—cotton textiles, cotton batting, and paint.

Textiles

Durable flame retardants based on tris(1-aziridinyl)-phosphine oxide (APO) and tetrakis-(hydroxymethyl)phosphonium chloride (Thpc) were developed at the Center (*59*) and have been commercially available for many years. In fact, retardants based on Thpc are the most widely used agents in the world for apparel, household goods, and certain military and industrial items.

However, passage of the 1967 Amendment to the Flammable Fabrics Act of 1953 increased the urgency of developing flame-retardant textiles that meet Federal standards. Thpc has now been modified or combined with other chemicals (*60*) to produce improved formulations that are durable through at least 50 home launderings. For example, when Thpc is reacted with sodium hydroxide, a mixture of methylolphosphorus compounds results, referred to as THPOH. This mixture with ammonia, which is now being used by industry, provides a useful new retardant that can be applied to even lightweight fabrics without loss of strength.

A major market for flame-retardant textiles is in children's sleepwear, now regulated by a Federal flammability standard. Flame-retardant clothing has permitted firemen to perform more safely and effectively and has saved the lives of industrial employees who work with molten or flammable materials or near open flames or sparks (fig. 5). Other applications include bed linens for home and institutional use, upholstery fabrics, cotton tufted rugs, and recreational fabrics, such as tentage. A recent specialized use for such treated cotton textiles is in high-pressure oxygen chambers where surgery is performed on blue babies and other patients with impaired circulation; besides being flame-retardant, the fabrics do not develop static electricity, which could ignite flammable materials in the presence of oxygen.

Current research is directed toward developing less expensive finishes that confer not only flame retardancy but also other desirable properties, such as resistance to abrasion, glowing, heat, and sunlight; satisfactory hand; and even greater stability to chlorine bleach.

Batting

Cotton Flote, a chemically treated cotton batting with improved resilience, coherence, and dimensional stability (*41*), was developed at the Center in cooperation with the Textile Waste Association, the National Cottonseed Products Association, the National Cotton Batting Institute, and the Foundation for Cotton Research and Education of the National Cotton Council. Because of its improved properties and performance, the batting product became competitive

[8] Mathers, W. A. Presentation at Fashion Flair Flame Free Design Conference, Houston, Tex. March 2–3, 1972.

FIGURE 5.—Flaming untreated cotton uniform and protective flame-retardant one.

with all types of cushioning materials, including polyurethanes and foam rubber, which had penetrated cushioning markets formerly held by cotton batting.

An extension of this research has now produced conventional cotton batting products that meet Federal flammability standards for cushioning used in automobile interiors and in mattresses (*44*). Because the Highway Safety Act, which concerned itself with automotive flammability, was the first law to be implemented, flaming combustion initially received most of the attention in testing. However, when a source of ignition such as a lighted cigarette impinges on padding material, it may smolder for hours without bursting into flame. Therefore, the Mattress Flammability Standard involves the evaluation of smoldering combustion initiated by cigarettes (fig. 6).

For cushioning in automobile interiors, raw stock can be treated with urea phosphate, borated amido polyphosphate, or dicyandiamide phosphoric acid. For mattresses, products that meet the standard can be prepared by the use of boric acid. Cost of treatment is low, less than 4 cents per pound of cotton fibers treated, including equipment writeoff over 5 years.

FIGURE 6.—Flame- and smolder-resistant cotton batting.

Paint

Few research developments have potential for simultaneously saving lives, protecting property, helping the defense effort, and restoring to agricultural commodities a market now dominated by synthetics. But fire-retardant paints (*76*) could do all four. They were developed in SRRC research supported financially by the U.S. Army Engineer Research and Development Laboratories and by the Pan American Tung Research and Development League. When these coatings are exposed to heat, they foam into a thick layer of carbon, protecting the underlying structure and preventing rapid spread of the flames.

The military need for such a product can be assessed by the participation of the Army in the research. Widespread civilian use, particularly in areas having many frame structures, would undoubtedly reduce loss of lives and property. Even during the research phase of development, the combination of fire retardancy and excellent conventional properties aroused the interest of several industrial companies, including two of the "Big Four" in coatings manufacture.

Abatement of Pollution

The results of research to abate pollution obviously are more likely to be accepted by industry if they offer economic as well as environmental advantages. At SRRC, therefore, research on pollution is directed toward this dual goal.

Cotton

Since textile processing can produce a considerable amount of air, stream, and noise pollution, research on cotton has offered an opportunity to help solve these problems. Although abatement of pollution only recently has been formally stressed as a research approach, improved processing efficiency, which reduces waste, has always been a part of SRRC research. And the less waste, the less pollution.

Air pollution in mills has been greatly decreased by individual machines developed to improve the cleaning and carding of cotton—for example, the opener-cleaner (*64*), granular card (*64*) (fig. 7), and fiber retriever (*53*). Developed in 1958 and now manufactured worldwide, the opener-cleaner is a high-production, efficient machine that is almost completely sealed, reducing dust and fly to a minimum. The granular card removed the worst source of air contamination in the mill by replacing the conventional open flats with a rigid airtight cover. And the fiber retriever increases cleaning efficiency and reduces the loss of spinnable fibers.

Although these individual machines have been valuable in reducing air pollution, creative SRRC engineers have long believed that the only real solution is a fundamentally new, enclosed system for continuously processing fibers into yarn (*64*). Basic studies on aerodynamics, ultrasonics, electrostatics, and other modern techniques gave promising preliminary results, and now progress toward the hardware stage is more rapid than anticipated. Within 10 years, there may be available to industry a completely automatic, closed system that eliminates the possibility of particles escaping into the atmosphere.

Like mills, textile finishing plants also have problems with air pollution. One of the primary sources is the release of formaldehyde from durable-press textiles. However, SRRC scientists recently discovered that a simple treatment—merely steaming fabrics for a few seconds—prevents the release of formaldehyde during manufacture of garments (*62*). Safety and comfort are increased, not only for textile workers but also for individual consumers, because the odor of formaldehyde is an irritant in retail outlets as well as in commercial plants.

Purification of liquid textile wastes is much more complex than most other industrial pollu-

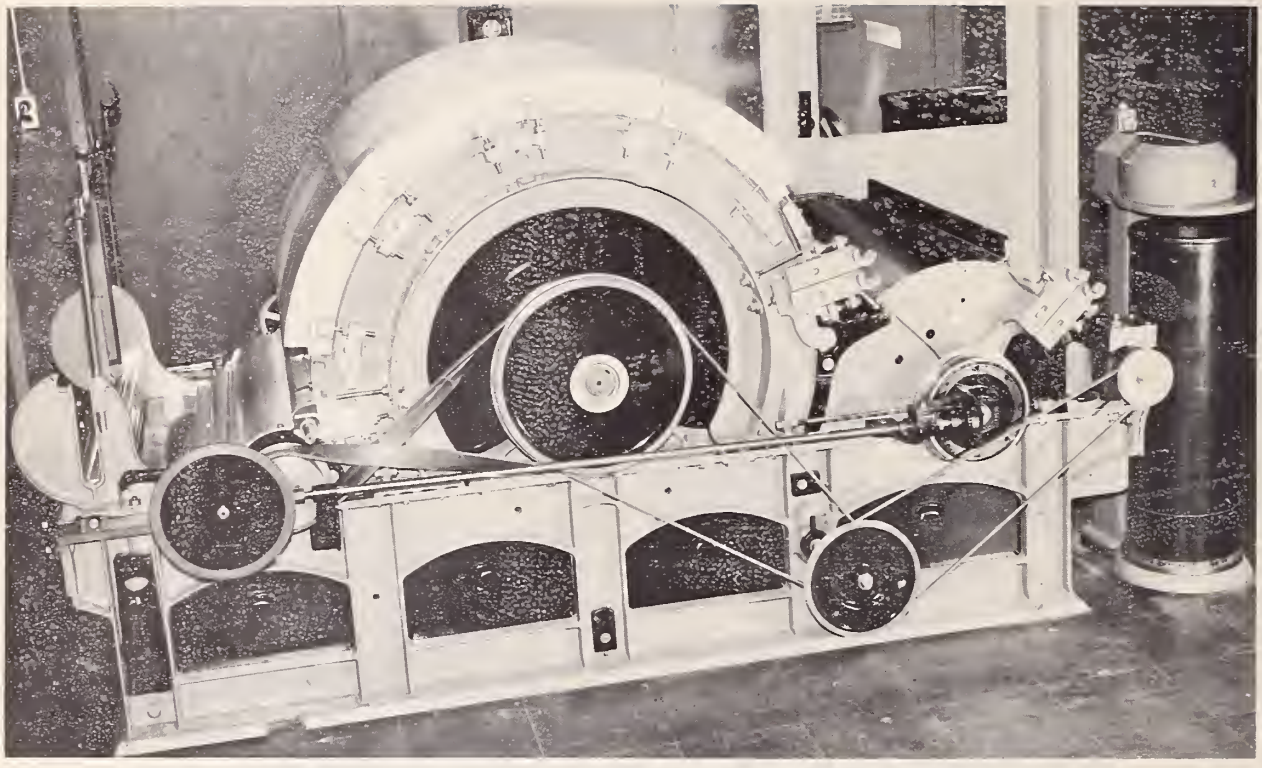

FIGURE 7.—Granular card has airtight cover to reduce air pollution.

tion problems because of the wide variation in type of wastes. Wastes from desizing, scouring, and mercerizing constitute about 70 percent of this objectionable effluent.

Two recent developments from SRRC research should help alleviate pollution from these stages of textile processing. The first is permanent sizing (*48*) to eliminate the usual desizing step that causes so much stream pollution. The new sizing consists of polymers such as polyurethanes or polyacrylates applied to yarn before it is woven. In addition to its usefulness in reducing pollution, permanent sizing has another advantage—a lower concentration of agents can be used to produce durable-press fabrics with better strength and abrasion resistance. The second development is an improved liquid-ammonia mercerization process (*15*) devised to replace conventional mercerization using sodium hydroxide. The ammonia can be reclaimed, and organic material removed from the fabric can also be collected and utilized instead of contributing to stream pollution. Again, there are other advantages: Not only is ammonia mercerization faster than conventional mercerization, but the properties of subsequently treated durable-press fabrics are also considerably improved.

Eliminating or reducing effluent from individual steps in the finishing of cotton, as just described, is one approach. Another approach is the use of nonaqueous agents throughout the total system of cotton finishing. Processes for the preparatory steps are already available either commercially or on a laboratory scale. Now SRRC scientists are studying methods for applying durable-press finishes to cotton fabric from organic solvents (*61*). The durable-press finishing process now used commercially is a pad-dry-cure process that does not involve the discharge of effluent at the finishing plant, but the excess and unreacted chemicals are discharged into municipal plants when the textiles are laundered in the home. Development of a nonaqueous system for durable-press finishing could provide the last link needed to permit industrial use of a completely nonaqueous finishing system.

In addition to air and stream pollution, noise pollution is now recognized as a major industrial problem. Enactment of the Occupational Safety and Health Act of 1970 (Public Law 91–596),

one provision of which requires manufacturers to control occupational noise, has greatly increased the importance of a quiet industrial fan developed by SRRC researchers in connection with their work on textile processing. Noise from centrifugal fans and blowers creates an acute problem in textile mills and in many other types of industry. To decrease turbulence—and thus noise—the researchers replaced the standard knife-edged cutoff with an airfoil that has a curved leading edge like an airplane wing (*52*). Again there is a dividend; the airfoil actually increases a fan's efficiency. Recognizing its potential contribution toward complying with the new law, four companies have been licensed to manufacture the fan, and a machinery journal has featured it in a story (*3*) that began, "Who says that technology can't contribute to improving the environment?"

Although the developments just discussed relate to the reduction of pollution caused by the processing of cotton, researchers at SRRC have not overlooked another intriguing possibility—that cotton itself can be used to remove pollutants from other materials. For example, previous research suggests that aminized cotton may be useful for this purpose (*5, 35, 36*). Since this type of cotton is positively charged, it should attract and immobilize negatively charged bacteria and possibly viruses in contaminated water. It should also remove mercury. And it can take up soil released from clothes during laundering.

Food Crops

Research on citrus has produced some notable examples of reducing pollution and simultaneously providing the consumer with better products at lower cost.

As previously noted, the development of nutritious frozen orange concentrate (*50*) opened a market that is today assessed at $1 million a day at the consumer level. However, in addition to nutritive and economic advantages, the use of orange concentrate instead of a comparable amount of fresh fruit makes these contributions to environmental quality:

1. Instead of generating garbage throughout the country, the residue is kept at processing plants, where most of it is dried for use as feed.

2. The fuel requirements for shipping are greatly reduced, conserving an important nonrenewable resource and reducing air pollution.

3. The packaging materials to be discarded weigh only a fraction as much as the residue from the fresh fruit and present a far less serious disposal problem.

In citrus processing, one of the worst pollutants with respect to biological oxygen demand is the liquid waste from the manufacture of cold-pressed peel oil. Scientists at Winter Haven, Fla., developed an evaporation method (*72*) for recovering volatile water-soluble aroma solutions and distilled oil from this waste material. Recovery of these products not only reduces organic content of the desludger effluent by 25 to 35 percent, but also provides ingredients that greatly enhance the flavor of frozen, canned, instant, and other citrus products.

In another development from Winter Haven, researchers extracted from peel a highly concentrated, colored material and then removed components that can affect flavor or odor (*9*). One use for this pigment is to enhance the color of juice from early-season oranges—an important result, since the appearance of citrus products is a major factor in consumer acceptance.

A process for making whole citrus products (*16*) was devised by researchers at Weslaco, Tex. Only the harder parts of the fruit—the whole seeds, scaly parts of the peel, and most of the rag—are separated and rejected. Since the remaining 85 to 90 percent of the whole fruit is converted into puree that can be used for flavoring, obviously the problem of waste disposal is greatly diminished.

The Weslaco laboratory also developed a process for peeling tomatoes by immersion in or spraying with liquid nitrogen, liquid air, or Freon just long enough to freeze the skin but not the flesh (*14*). When the skin thaws, it slips off readily if broken or cut. In comparison with commercial methods, the new freeze-peeling process cuts losses in half, reduces labor costs, and yields a firmer product with better color.

The most acute waste disposal problem in commercial processing of sweetpotatoes results from the caustic peeling operation. In this operation, the caustic, the peel, and other materials are introduced into large volumes of water and end up as pollutants in processing plant effluents. However, a new peeling process, called dry caustic peeling because it removes most of the peel tissue

mechanically without the use of water, can greatly reduce this effluent. The process, originally developed by the Western Regional Research Center for white potatoes (*34*), has now been modified for sweetpotatoes through a cooperative effort.[9]

Researchers at the Winter Haven laboratory have devised several processes for obtaining flavorful celery oil from leaves, tops, and outer ribs, parts of the fresh celery plant now discarded as trimming waste (*75*). The preferred process—continuous atmospheric distillation—yields an oil whose flavor and aroma closely resemble that of fresh celery. A ton of waste yields as much as 250 milliliters of oil, theoretically enough to flavor the dried product from a ton of celery. In addition to improving the flavor of processed celery products, the oil should find widespread use as a seasoning for other foods. It has a better flavor and is more potent than oil extracted from celery seed or made synthetically.

Chemifoams

New chemifoams (fig. 8) developed by SRRC scientists in cooperation with Louisiana State University School of Agricultural Engineering (*67*) have considerable potential for protecting the environment: They not only prevent agricultural chemicals from drifting but also reduce the total amount required. They also offer protection from severe freezes like the ones that devastated entire crops over a wide area—the citrus crops in South Texas and in Florida, for example. In addition to affording protection from the cold, these foams can serve as carriers for insecticides, herbicides, fungicides, defoliants, and other agricultural chemicals; provide soil covers after fumigation to destroy nematodes and other pests; and mark treated areas of a farm.

Various materials are being evaluated as stabilizers to give the foams strength, form, capability of forming skins, and durability. Some of the most promising stabilizers are whey solids, glue from animal hides, starches, and byproducts from the production of oilseed proteins. The formulation based on whey is particularly advantageous. It has good properties and is about 35 to 40 percent cheaper than foams based on gelatin or starches. In addition, use of this formulation would help solve a serious environmental problem—disposal of the huge quantities of whey produced in cheese manufacturing, one-half to two-thirds of which now goes to waste.

FIGURE 8.—Chemifoam being applied to row crop.

Control of Contaminants in Food

Contamination of food presents a complex health problem throughout the world. Contaminants are not only ubiquitous but also diverse. Some, like insects, are well known and easily visible; others, like bacteria, are known but are microscopic in size; still others, like aflatoxins, are chemical substances that were unknown 15 years ago and can now be detected only with sensitive techniques.

Insects

SRRC research has made two separate contributions to protection from insects, development of a chemosterilant and development of insect-resistant bags for storing and shipping grains.

The chemosterilant—a unique type of phosphorus compound—was a byproduct of research on the modification of cotton. In later coopera-

[9] Spadaro, J. J., Ziegler, G. M., Jr., Gallo, A. S., and Huxsoll, C. C., unpublished information, 1970.

tive research, scientists at SRRC prepared the compound for Agricultural Research Service's former Pesticide Chemicals Research Branch, Entomology Research Division, which found it 80 to 98 percent effective in sterilizing house flies that ate it or even walked over it. Since insects may become resistant or immune to insecticides, use of such a chemosterilant has considerable advantages in reducing or eradicating a target population.

In cooperation with the Textile Bag Manufacturers Association, SRRC and the Stored-Product Insect Research and Development Laboratory conducted investigations to develop insect-resistant bags. Besides the primary objective of the research, initially a secondary goal was to use repellents that were removed by laundering, so that fabrics from the bags could be made into clothing, particularly in developing countries. Later Agricultural Research Service studies led to a different type of cotton bag that was far more effective in preventing infestation (*37*). Treated with insect repellent and constructed with tape-over-stitching closures, kraft liners, and an inner barrier ply of creped saran-coated kraft, this type of bag provided good protection from infestaton for 9 to 12 months. Migration of insecticide into the foodstuffs was minimal, well within legal tolerance.

Salmonella

Salmonellosis affects more people and more animals than any other single disease; in fact, some authorities estimate that the 20,040 reported isolations of *Salmonella* from man in the United States in 1968 were only 1 to 2 percent of the true incidence (*69*). Contamination with *Salmonella* can originate from man, domestic animals, rodents, insects, birds, and even from airborne dust.

SRRC researchers studied the incidence of salmonellae in cottonseed and its products at various times during processing (*68*). Three types of oil mill operations were examined: Screw-press, prepress solvent extraction, and direct solvent extraction. Salmonellae found in the screw-press oil mill were killed in the cooking operation; in the direct solvent extraction oil mill, they were killed in the desolventization operation. Salmonellae were not found in the prepress solvent extraction oil mill; however, if organisms had been present, they would have been killed in the cooking operation. Conditions of time and temperature were determined for destroying salmonellae during processing, and guidelines for producing salmonellae-free products and for preventing recontamination were also developed.

Fungal Metabolites

Mycotoxins, which are toxic metabolites produced by molds, have been known for centuries, but their importance to the safety of foods was not recognized until comparatively recently (*32*).

SRRC's research on mycotoxins in foods began in the 1950's, when the discovery of fungal toxins in rice imported by Japan threatened to drastically curtail our large exports to them. The rice turned yellow and became bitter, but fortunately was not extensively consumed by human beings (*54*). However, in an investigation conducted by the Japanese Ministry of Public Health, human subjects fed a regulated amount experienced generalized weariness and gradual appetite loss. Latent hypovitaminosis of B_1 and B_2 and disfunction of the liver were also evident.[10] The causal fungus was identified as *Penicillium islandicum*, which produces at least two components that are hepatotoxic and at least one carcinogenic to rats.

At SRRC, Japanese and American scientists examined thousands of grains of rice produced in the South and concluded that they were virtually free from fungi (*46*). A comparable survey conducted by the Western Regional Research Center showed that short-grained rice grown in California was also essentially uncontaminated. On the basis of these findings, the Japanese government removed its restriction on the purchase of U.S. rice.

However, this incident and others involving mycotoxins in foods did not attract much attention, even among specialists. Then, in 1960, the situation changed abruptly when thousands of young turkeys, ducklings, and other fowl died in England from a mysterious disease dubbed turkey X disease. The common ingredient in their food was rather quickly identified as an import-

[10] Inoue, I. Abstracts of the tests of the toxicity of the deteriorated rice. Ministry of Public Health and Welfare, Japan, 1954, 22 pp.

ed peanut meal. Within a year, the cause of the disease was discovered to be a toxic material produced by the common mold *Aspergillus flavus*. This toxic substance was christened aflatoxin after the name of the mold.

The occurrence of turkey X disease and related incidents in many countries, including the United States, generated intense interest and research throughout the world. In fact, at SRRC alone, the program has been extensive.

The first survey of the incidence of aflatoxin in peanuts demonstrated that aflatoxins could sometimes be found in peanuts grown in all parts of the United States. This survey was an important factor in developing USDA's contract program for the marketing of the 1964 peanut crop. That program—an excellent example of cooperation between Government and industry—insured that only high-quality peanuts were marketed for food and that those not meeting the standards were channeled into nonfood uses.

In the years since then, a major effort at SRRC through in-house and contract research has been devoted to many aspects of the aflatoxin problem (*30, 31*). Rapid and accurate analytical methods were developed for determining aflatoxin in cottonseed, peanuts, and other commodities. Aflatoxin reference standards were prepared and distributed throughout the United States and to more than 60 foreign countries. This undoubtedly improved the accuracy and reliability of reports of aflatoxin content in various agricultural commodities and consumer products throughout the world. Limiting environmental conditions for the development of aflatoxins were determined. Their effects on laboratory and farm animals were assessed, including possible transmission into milk, eggs, and animal tissues. Practical methods were devised for removal of aflatoxins by solvents and for destruction by chemicals such as ammonia. Two commercial plants for continuous ammoniation of cottonseed meal contaminated with aflatoxins are in operation.

Many questions about aflatoxins remain to be answered; many problems remain to be solved. But perhaps progress in one area, analytical methodology, can serve as a yardstick of composite progress during the past decade. In the early research, 3 days were needed to complete an analysis; now, as a result of work at SRRC and elsewhere, it takes 1 to 2 hours—and a rapid screening procedure can be completed in 15 to 20 minutes (*17*). For their contributions to composite progress—prevention, detection, analysis, inactivation, and removal—SRRC scientists have been recognized around the world.

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